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Developing and Evaluating Collaborative Technologies

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DEVELOPING AND EVALUATING COLLABORATIVE TECHNOLOGIES

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A sociotechnical approach examining the impact of new technologies on a system is needed if we are to tailor future technologies to real world needs, and to provide useful guidance to designers and implementers of existing technologies. However, evaluating CSCW technologies is not a trivial undertaking. This paper considers the topic of assessing collaborative technologies in the context of military logistics. A historical view of collaborative research in military logistics is provided, as well as a discussion of current research aimed at developing a framework for assessing collaborative technologies.

INTRODUCTION

As the need for communication and collaboration among distributed teams has increased, the world has seen an explosion in software and hardware technologies (e.g. web conferencing, shared whiteboards, etc.) intended to support a range of complex work activities related to decision making, planning, problem solving, etc. Systems engineering design methodologies used to develop collaborative systems have not kept pace with the increasingly complex collaboration required in today's military. Transaction based processing systems that were primarily designed to support single users interfacing with a computer – not the collaboration among multiple users and systems – are no longer sufficient. Potential users of these technologies and systems can find the technical options overwhelming and difficult to compare. In fact, few methodologies, frameworks, or metrics have been offered to evaluate how individual, and team performance is impacted by the introduction of collaborative technologies and systems in organizations. As a result, technologies are often purchased and placed within an existing organizational structure with little understanding of how the technology changes the way work gets done and how it will support or hinder a team (and organization) in accomplishing its goals.

The Air Force Research Laboratory, Logistics Readiness Branch (AFRL/HEAL) has championed applied research in the domain of aircraft logistics and maintenance teams for several decades. Within this context, the types of collaboration, as well as the technologies designed to support collaboration have evolved significantly. AFRL/HEAL has a long history of researching and developing processes and tools to enable Air Force wing and depot level decision makers to support Agile Combat Support and the Air Expeditionary Force. More specifically, research programs have centered around processes and technologies to improve Logistics Command and Control through improved flightline status information, decision aiding and information visualization.

Within this context, collaborative research has moved through several stages:

- Portable Computing. The introduction of portable computing devices to enable real-time data entry increased the ability of an individual maintainer to access and record data on the flight line. This human-computer collaboration resulted in more efficient use of the maintainer's time as well as a decrease in memory errors.
- Information Integration. As increased computing power became available, the US Air Force moved away from relying on a range of individual databases and began to explore strategies for merging information into integrated displays. This approach leveraged strategies for linking databases so that human users could interact with a single technology rather than extracting information from a range of sources. Important results from this research included reduction in both time and errors when troubleshooting complex aircraft systems.
- Decision Support. Given the success of information integration efforts, the next phase focused on evaluation of processes and development of technologies to facilitate situation awareness across levels of command to support complex processes such as decision making, planning and problem solving.
- Collaboration in a complex socio-technical system. As software and hardware applications designed to enable collaboration have become increasingly available, more complex collaborations are envisioned. However, strategies for assessing the impact of technology on collaboration – particularly collaboration across agencies or teams – have not kept pace. Current AFRL/HEAL research focuses on exploring methods, tools, and measures to assess the impact of a range of collaborative technologies on their target environments. The ultimate objective is to inform the design, implementation, and sustainment of systems intended to support the overall process of collaboration.

Examples of each stage of this evolution are described in turn.

PORTABLE COMPUTING

Since 1976, AFRL has conducted several research and development projects to create technology for the presentation of technical data on an automated system. From 1976-1988, these efforts included the development of two prototype systems to support maintenance activities, including the development of a portable computer system for presentation of technical data at the flight line (Ward, Kruzick, & Weimer, 1995). Figure 1 shows an aircraft maintainer using a portable computing system. This work demonstrated that the presentation of maintenance technical data on a computer-based system was feasible. More importantly, this early work provided many advances in human computer interfaces, including data presentation techniques and early information integration methodologies, providing important foundational research that would inform more complex collaborations in the years to follow.

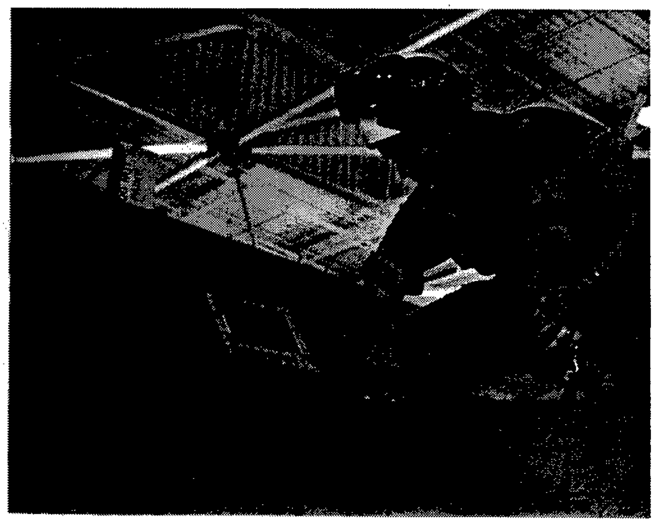

Figure 1. Aircraft maintainer with portable computing device

INFORMATION INTEGRATION

This early work led to the development of the Integrated Maintenance Information System (IMIS), a tool to access, format, and display maintenance data from multiple sources to the user (Ward, Kruzick, & Weimer, 1995; Thomas, 1995). The IMIS program not only demonstrated the information integration concept, but also

demonstrated the potential of these IT tools to positively impact the entire Air Force maintenance community. The next step was to expand this work to the depot level. This program, called Integrated Technical Information for the Air Logistics Center (ITI-ALC) built on the early information integration work to improve the effectiveness and efficiency of depot aircraft maintenance by designing, developing, and demonstrating technology to improve, standardize, integrate, and make maintenance and management information accessible at the job (Faas, Batchelor, & Quill 1998).

Taking a more global view of the logistics process, research at AFRL evolved to address various aspects of the deployment process in terms of both scope and perspective. This project, called the Logistics Contingency Assessment Tool (LOGCAT) investigated tools and processes to improve wing-level *deployment planning* and execution for short-notice contingencies (Leftwich, et al, 1997). The objective, once again was to provide a set of automated tools to assess beddown capabilities of deployment bases, survey tools to collect data potential deployment locations, and tracking tools to maintain an awareness of equipment/troops/supplies. The work at AFRL/HEAL had evolved by this time to not only provide a medium for collection of logistics data in a multimedia type format, but also a central knowledge base to provide functional area planners rapid access to crucial deployment planning information.

DECISION SUPPORT

Building on the success of these early programs, and addressing the continually changing needs of the Air Force, AFRL/HEAL moved into a line of exploratory research to evaluate processes, and develop and integrate information technologies that would provide benefits to the user, including minimized search time, reduced data interpretation, predictive simulations and dynamic re-planning. Coupled with advancements in on-board diagnostic systems and decision aiding information systems, AFRL/HEAL successfully provided a series of tools that begin to support collaborative problem solving for the maintainer and deployment planner.

One example is the Logistics Control and Information System (LOCIS), a collaborative technology intended to provide decision support and improve team situation awareness from the individual maintainer up to the wing commander (Militello, Quill, Vinson, Stilson & Gorman, 2003). LOCIS provides up-to-date scheduling and maintenance information via a small set of displays, each depicting key information that can be viewed at varying levels of detail depending upon the role of an individual user (i.e., Figure 2). Further, the LOCIS prototype includes large-screen displays to support collaborative team decision making and problem solving during high-intensity, dynamic situations.

A second example focuses on supporting collaboration with experts throughout the maintenance process. Much of maintenance

Figure 2. Sample LOCIS display

expertise is gained on the job, and is often highly specialized. At times, finding the person who has experience with a particular problem can mean the difference between hours and weeks of repair time. The Aircraft Maintenance Intuitive Troubleshooting (AMIT) project has developed innovative approaches to provide access to experts and expert knowledge in context.

In the context of the AMIT project, investigators have discovered that novice maintainers are reluctant to collaborate with a more experienced personnel because they see this type of collaboration as an admission of defeat. As a result the AMIT team is currently investigating technology and process solutions to guide, prompt, or urge the novice user to collaborate when appropriate. A related issue is that of task complexity. As task complexity increases, the need for multi-modal collaboration increases. For example, getting a yes/no answer can be done over the telephone. However, if collaboration involves communicating a 10-character part number, or the on-aircraft location of a part or panel, then a text or visual collaborative capability improves performance. This distinction regarding the type and complexity of information to be communicated has important implications for the design of collaborative technologies (Bachman, et al, 2005; Kancler, Bachman, Curtis, Stimson, 2005).

COLLABORATION IN A COMPLEX SOCIOTECHNICAL SYSTEM

Recent conflicts have highlighted shortcomings in current collaboration methods for combat support and in technologies for logistics command and control. In response, a DoD-wide transformational vision of logistics has evolved that calls for rapid, coordinated action of distributed teams operating advanced, interlinked information networks to achieve desired combat effects. Transformational concepts for combat support are currently embodied in the terms Sense/Respond Logistics (S/RL) Capability and Network-Centric Warfare (NCW) (*Department of Defense, 2005*)

NWC broadly describes the combination of strategies, emerging tactics, techniques, and procedures, and organizations that a fully or even a partially networked force can employ to create warfighting advantage. S/RL, sometimes referred to as Knowledge Enabled Logistics, is tied closely to NCW theory and practice. In general, it is an adaptive method for maintaining the operational availability of units by managing their end-to-end support network. It can be summarized by a series of attributes: it facilitates shared awareness, it is adaptive, it is flexible and it allows dynamic synchronization. This concept of warfare has major implications on the logistics of warfare, including war and emergency response planning.

Enabling concepts such as Service Oriented Architectures and the Global Information Grid, which are currently being implemented, emphasize the networking and automation aspects of the Sense and Respond Logistics concept. What is still lacking is a full consideration of the human aspects of system operation, and in particular how to measure and improve team-network interaction in this context. The powerful networked computing environments supporting the implementation of collaborative technologies and applications will not reach their full potential without explicit consideration of the human element. From this emerging philosophy AFRL/HEAL has set a new course for future research. The Team-based Assessment of Sociotechnical Logistics (TASL) program seeks to address this gap by researching and developing enhanced or novel methodologies and measures for evaluating the impact of distributed collaboration on team-network performance.

A first step in exploring complex collaboration used an analogous domain to investigate logistics challenges and cross-agency collaboration. AFRL/HEAL sponsored a county-level emergency management exercise in which a tornado wreaked havoc across a primarily urban and suburban county in Ohio. Representatives from local government, the American Red Cross, SBC 911, the hospital association, fire, police, and others participated in the exercise. Participants reported to the county Emergency Operations Center and fielded calls from confederates playing the roles of incident command, dispatch, media, state government, military, and other members of the community likely to call the Emergency Operations Center during an incident. Observers noted barriers to collaboration and logistics challenges. Figure 3 depicts a diagram of information flow through the emergency operations center, highlighting asymmetries and fragmented situation awareness.

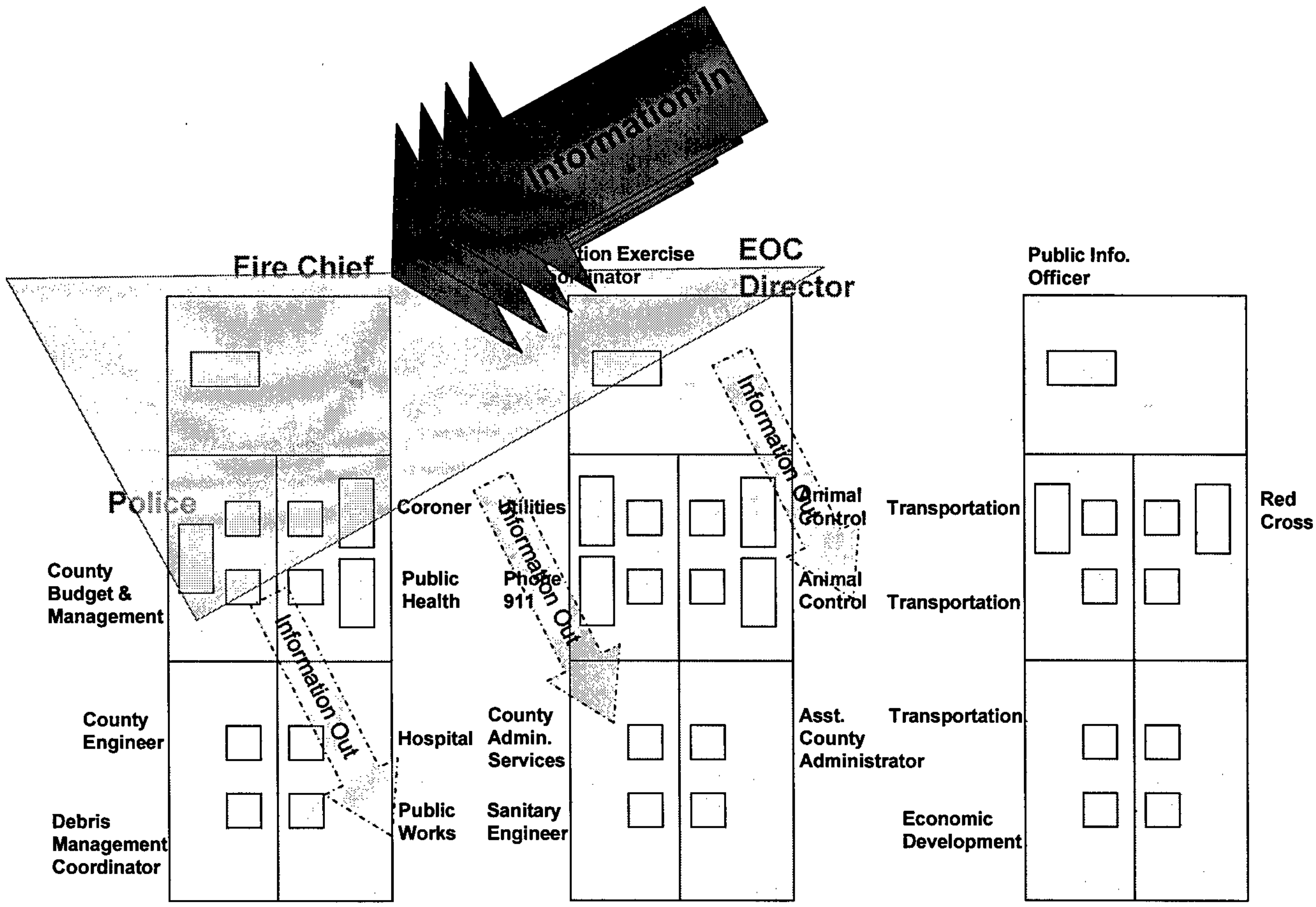

Figure 3. Information flow in the Emergency Operations Center

This exercise represented an important first-step in understanding the types of challenges that occur in complex collaboration and how technologies either support or hinder activities (Militello, Patterson, Wears, & Snead, 2005; Militello, Quill, Patterson, Wears, & Ritter, 2005).

The TASL project will advance these efforts by developing a framework for assessing collaborative technologies from a human and organizational perspective, recognizing that simply testing collaborative technologies and systems from a reliability and network connectivity standpoint does not guarantee successful implementation. A socio-technical approach examining the impact of new technologies on a system is needed if we are to tailor future technologies to real world needs, and to provide useful guidance to designers and implementers of existing technologies. However, evaluating CSCW technologies is a difficult task and suggests many challenges —especially when expanding this research into today's military environments, which are dynamic, chaotic, highly distributed, and culturally diverse. The design and development of meaningful metrics to evaluate the human and organizational impact of CSCW technologies and systems in these settings will be challenging. Such research will require a combination of traditional experimental methods and ethnographic techniques. It will be important to consider how well technologies support basic team processes such as communication and document sharing, as well as more complex functions such as team decision making and shared situation

awareness. Further, the often negative impact of technologies on conation or work motivation has been well-documented (Wainfain & Davis, 2004). Evaluation techniques that would indicate whether a given technology is likely to exacerbate or ameliorate these problems are needed.

PROPOSED FRAMEWORK

A framework for assessing sociotechnical systems will likely include both laboratory and field experiments. Research will be centered around the problem statement that critical information is not getting to the right people when they need it. Three key research areas have been identified:

- organizational structure
- makeup of team
- processes and technology

To provide adequate context for investigating these research areas, Polivka's (1995) model for interagency collaboration is under consideration (Figure 4). Although this model was developed in the context of community health agencies – a domain which differs considerably from military logistics – the model provides an initial conceptual structure for investigating collaboration.

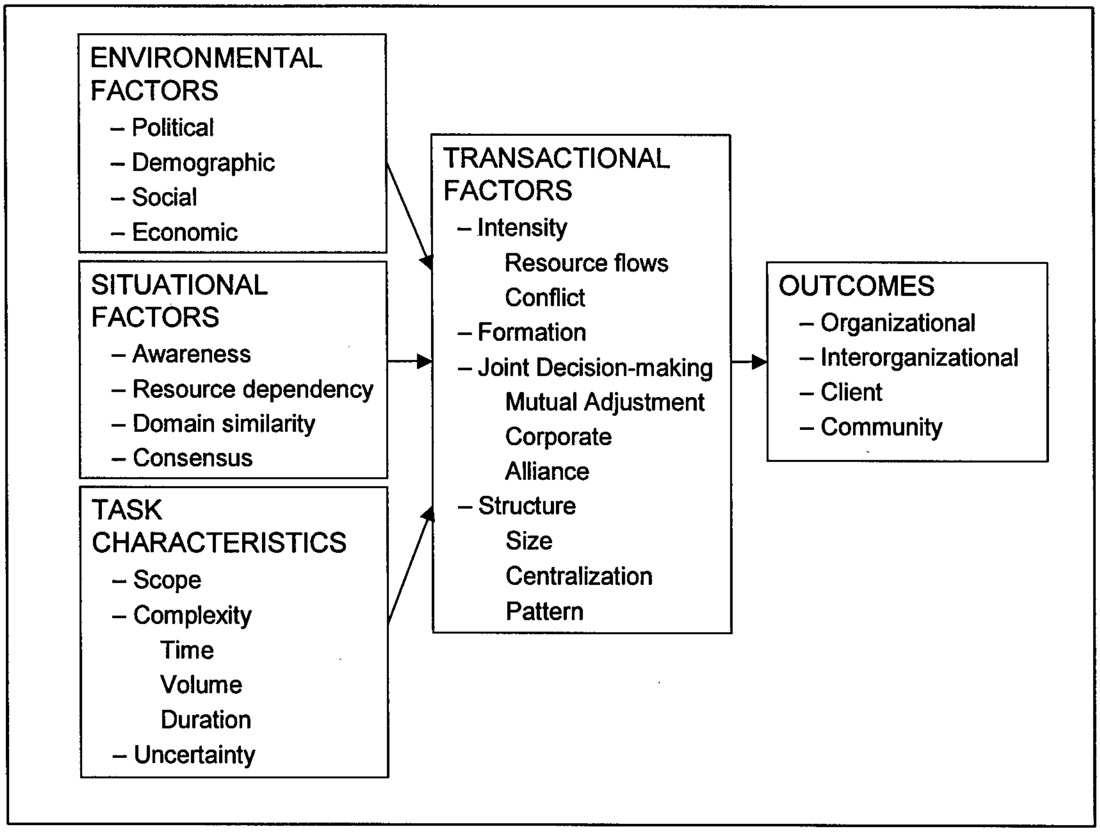

Figure 4. Conceptual Model of Interagency Collaboration (Polivka, 1995)

Scenario design

This model will provide an important structure for investigating collaboration. *Environmental Factors*, *Situational Factors*, and *Task Characteristics* can be manipulated or controlled in laboratory studies, as well as exercise-based field studies. It will be important to take into consideration each of these elements in designing and selecting scenarios to be used. In addition, a discussion of these factors will be key to interpreting the generalizeability of findings from one study to another. It is likely that collaborative tools will be used differently in the

context of different environmental factors, situational factors, and task characteristics.

Process measures

The elements identified as *Transactional Factors* will be important indicators of team process. Ethnographic methods such as observations and interviews in combination with communication logs can be used to explore how resources and information flow, what conflicts arise, how coalitions form (either as supported by or in spite of prescribed roles and functions), etc. Research will explore how these and other transactional factors are supported or hindered by collaborative technologies in the context of different environmental factors, situational factors, and task characteristics.

Outcome measures

Outcomes can be explored at different levels. Polivka offers four levels important in community health agencies: organizational, interorganizational, client, and community. In the context of military logistics, the outcomes of collaborative team-based activities (e.g., development of a force deployment plan involving multiple functional disciplines) might be assessed at the unit, service/agency, joint, or national level. While each of these levels should be in alignment and contribute to the overall objectives of a campaign, outcome measures related to overall objectives would be tailored to each respective organizational level under study. In designing outcome measures, it will be important to consider which level(s) of outcome are most important for a given study.

DISCUSSION

Developing a framework for evaluation of collaboration technologies is an ambitious undertaking. However, as technology intended to support collaboration has evolved and the types of collaboration proposed have become increasingly complex, the need for an evaluation framework has become ever more crucial. Advancing our understanding of these complex issues will require both a historical perspective examining how collaboration has occurred in the past, as well an eye to the future in search of theory and methods to drive evaluation and design of sociotechnical systems. A focus primarily on technological capabilities is not sufficient. Research in this area will require a multi-disciplinary approach drawing from ethnography (McCracken, 1988; Seale, 1999), cognitive engineering (Cooke, Salas, Kiekel, Bell, 2004; Klein & Militello, 2001; Vicente, 1999; Schraagen, Chipman, & Shalin, 2000), CSCW (Borghoff & Schlicher, 2000; Hawryszkiewycz, 1997), and other disciplines.

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